designed and built, with much of the work done at Ames by the AIRES team. In previous tests, the detector configuration sketched in figure 1 was shown to work well. During FY00, testing of the amplifiers and design and fabrication of a 2 x 24 protoflight detector module have made great progress. This unique detector system, essential for the success of AIRES, is well on its way to achieving its design performance.

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The World's Largest Grating

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The airborne infrared echelle spectrometer (AIRES) is a high-resolution grating spectrometer under development as a facility science instrument for the Stratospheric Observatory for Infrared Astronomy (SOFIA). An echelle is a grating used at a steep angle of incidence relative to the incoming light beam. The spectral resolution of a grating spectrometer is directly proportional to the projected length of its grating along this beam and inversely proportional to the wavelength of light being analyzed. AIRES is designed to measure far-infrared (long-wavelength) spectral lines of molecules and atoms originating in the interstellar medium. Therefore, AIRES requires a grating significantly longer than any previously made. In fact, the wavelength range and resolution planned for AIRES demands the world's largest grating!

Further, the entire AIRES optical system must be operated at a few degrees kelvin (near absolute zero). To minimize problems associated with thermal contraction in this cryogenic environment, to facilitate diamond machining, and to ensure long-term stability, a monolithic aluminum blank was chosen. This blank was manufactured from 152-millimeter (mm)-thick, aluminum alloy 6061-T651, Type 200 tooling plate. The final blank is 102 mm thick, 267 mm wide, and 1067 mm long with the corners removed to provide a near-elliptical planform.

The blank was light-weighted by cutting triangular-shaped slots with a wire-electric-discharge machine, which builds less stress into the blank than conventional milling and has the ability to cut deep slots with small corner radii. The resulting truss-like structure is symmetric, provides good specific stiffness, and is 70%-light weighted. Before final machining, the blank was heat-treated at 375 degrees Centigrade (°C) for 2 hours and then thermally cycled 7 times between –200°C and 100°C to obtain the required stability.

A groove spacing of 980 microns, an apex angle of 90 degrees, and a blaze angle of 76 degrees were selected to optimize the packaging and optical performance of the grating at the wavelengths of interest. This combination of parameters maximizes the spectral resolution for the 63- and 145-micron neutral oxygen, 157-micron singly ionized carbon, and 205-micron singly ionized nitrogen transitions arising from the interstellar medium, without adversely affecting performance for other high-priority transitions.

The grating was ruled under contract with Hyperfine, Incorporated, of Boulder, Colorado, with a fly cutter using a single-point diamond turning on a custom ruling engine. The completed grating is shown in figure 1. The light-weighting truss structure is evident along its

Fig. 1. The AIRES echelle is the largest monolithic, fully phased grating in the world.

front edge. Two reflections of the technician are visible; the front reflection originates on the long, 14-degree groove facets, and the rear reflection originates on the steep, 76-degree groove facets.

To achieve the desired optical performance, the AIRES optical system must have a total root-mean-square (rms) wave-front error (WFE) less than 1.5 microns. A detailed error analysis apportioned 0.8-micron rms WFE to the echelle grating. This WFE includes contributions from both absolute and periodic errors in groove position, shape, straightness, and fanning, as well as gross deflections of the blank due to self-weight, tool forces, and variations in thermal contraction. Interferometric tests of the completed grating measure a WFE of 0.3-micron rms—much better than required. This result implies that the surface is flat to about one part in 7 million. Other optical tests confirm that the efficiency and scattered light properties of this grating are acceptable for use in AIRES. The world's largest echelle grating has been successfully ruled and tested; the associated opto-mechanics, cryostat, detectors, and software for AIRES remain under development.

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